ATSB
Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

MARINE SAFETY INVESTIGATION
REPORT 170

Independent investigation into the disabling of the Antigua and Barbuda flag general cargo vessel

ANL Purpose

in the Coral Sea
on 6 August 2001

AUSTRALIAN GOVERNMENT — DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Department of Transport and Regional Services
Australian Transport Safety Bureau

Navigation Act 1912
Navigation (Marine Casualty) Regulations
investigation into the disabling of the Antigua
and Barbuda flag general cargo vessel
ANL Purpose
in the Coral Sea
on 6 August 2001

Report No 170
August 2003

ISSN 1447-087X
ISBN1 877071 35 8

Readers are advised that the Australian Transport Safety Bureau investigates for the sole purpose of enhancing transport safety. Consequently, Bureau reports are confined to matters of safety significance and may be misleading if used for other purposes.

Investigations commenced on or before 30 June 2003, including the publication of reports as a result of those investigations, are conducted in accordance with the *Navigation (Marine Casualty) Regulations 1990*, made pursuant to subsections 425(1)(ea) and 425 (1AAA) of the *Navigation Act 1912*.

Investigations commenced on or after 1 July 2003, including the publication of reports as a result of those investigations, are authorised by the Executive Director of the Bureau in accordance with the *Transport Safety Investigation Act 2003 (TSI Act)*. Reports released under the TSI Act are not admissible as evidence in any civil or criminal proceedings.

It is ATSB policy to publish such reports in full as an educational tool to increase awareness of the causes of marine incident reports so as to improve safety at sea and enhance the protection of the marine environment,

To increase the value of the safety material presented in this report, readers are encouraged to copy or reprint the material, in part or in whole, for further distribution, but should acknowledge the source. Additional copies of the report can be downloaded from the Bureau's website www.atsb.gov.au

Australian Transport Safety Bureau
PO Box 967
Civic Square ACT 2608
AUSTRALIA

Phone: 02 6274 6478
1800 621 372
Fax: 02 6274 6699
E-mail: marine@atsb.gov.au

CONTENTS

FIGURES

FIGURE 1:
ANL Purpose berthed alongside the repair wharf of Forgacs shipyard in the Brisbane River

Summary

At 2100 on Monday, 6 August, the small general cargo vessel *ANL Purpose* was at the position 18° 23.6' S, 152 54.3' E making good 11 knots on a course of 174° (T) on passage from Lae, New Guinea, to Melbourne. The weather was fine. The nearest land was Marion Reef, 45 nautical miles to the south west and Lihou Reef, some 76 nautical miles to the north west. The master was on watch on the bridge and the chief engineer was in his cabin, when an engine alarm annunciated.

Upon investigating, the chief engineer heard loud noises coming from the main engine, which he promptly stopped. After opening the port crankcase door on no. 4 unit, he saw that both the piston and the cylinder liner had shattered into numerous small pieces and the engine sump was full of debris. There was also significant damage to the engine block. The chief engineer realised that it would not be possible for the ship's staff to carry out repairs sufficient to restart the main engine, even on five cylinders and, at 2215, he advised the Master accordingly.

The master informed the vessel's owner and AusSAR (the Australian Search and Rescue Co-ordination Centre) of the vessel's predicament. *ANL Purpose* was drifting, in a mainly north-westerly direction, at a speed of approximately 1.3 knots. It was, however, in no immediate danger.

At 1654 on 8 August, the Townsville-based tug *Giru* made a rendezvous with *ANL Purpose* which had, by that time, drifted to a position of 17°59.1' S, 152°15.1' E, and passed a tow to the ship. The tow, at a speed of 7 to 7½knots, proceeded towards Brisbane in good weather with light south-easterly winds.

On 10 August, in the shelter of Saumarez Reef, the tow was taken over by the Brisbane-based tug *Bulimba*. The good weather held for the remainder of the tow to Brisbane and, on 12 August, *ANL Purpose* arrived at the repair wharf of Forgacs Cairncross shipyard in the Brisbane River.

The investigation concluded that:

- The proximate cause of the failure was the partial seizure and consequent break-up of the piston in no. 4 unit. The partial seizure was brought on by an obstruction to piston cooling oil flow caused by the axial movement of the bottom-end bearing shells, which may have been incorrectly fitted.
- The piston in no.4 unit was suffering from significant fatigue cracking, as were those in nos.1 and 2 units, and the additional loading from the partial seizure was sufficient to cause the break-up of the piston.
- The pistons were those originally fitted sixteen years earlier and there was no evidence that they had ever been replaced or crack-detected during that time. The engine manufacturers had issued service bulletins relating to the maintenance and crack-detecting of the later two-piece type of pistons, but not for the original, one-piece type.
- The standard of maintenance records kept aboard the vessel was less than adequate.

The report recommends that the engine manufacturer consider issuing a service bulletin covering the crack-detecting of any of the earlier, one-piece, pistons which may still be in service.

Sources of Information

Master and chief engineer

Foroohari Schiffahrts KG

ETRS (HRL Materials Consulting Group)

The Salvage Association

Wärtsilä-NSD, Sydney

German Federal Ministry of Transport

Australian Maritime Safety Authority

ANL Purpose

At the time of the incident, *ANL Purpose*, (which later reverted to its original name of *Esperanza*) , was an Antigua and Barbuda flag general cargo vessel, registered in Hamburg and owned and operated by Foroohari Schiffahrts KG, of Hamburg, Germany (figure 1). The ship operated a regular service from Port Moresby and Lae in Papua New Guinea, to the Australian ports of Melbourne, Sydney and Brisbane on an approximate 22-day cycle. The usual cargoes were coffee, tea and scrap metal.

The vessel, which had undergone six name changes prior to the incident, was built in Hamburg, Germany, by J.J. Sietas KG Schifftswerft GmbH & Company and launched in 1985. Since building it had been maintained in class with Germanischer Lloyd as a 100 A 4 E2 multi-purpose vessel with UMS (unmanned machinery spaces) notation.

ANL Purpose is 88.6 m in length overall (80.86 m between perpendiculars), has a moulded depth of 8.31 m and a maximum beam of 15.68 m. It has a gross tonnage of 3120 and a summer deadweight of 3650 tonnes at a summer draught of 6.05 m. All accommodation and machinery spaces are aft of the forward engine room bulkhead. Forward of the engine room is one single cargo hold, 53.3 metres in length, capable of accommodating 112 TEU (twenty foot equivalent units), while on the hatch covers there is capacity for a further 144 TEUs. Reefer points are fitted for 30 refrigerated containers. The vessel is fitted with two deck cranes each of 30 tonnes lift.

ANL Purpose is powered by a single 6-cylinder, four-stroke, Wärtsilä Vasa GR32 diesel engine of 320 mm bore and 350 mm stroke. The engine develops 1495 kW (2032 shp) at a constant speed of 720 rpm and drives a single shaft with a controllable-pitch propeller, giving the ship a maximum speed of 13.7 knots and an average service speed of 12.5 knots. When either manoeuvring or on passage, the engine is fuelled by blended heavy fuel oil (IFO), with a viscosity of around 100 cSt, although it may be run on diesel fuel if necessary. The ship is also fitted with a 184 kW bow-thruster unit.

Electrical power at sea is provided by a 935 kVA shaft generator. In addition, the ship is fitted with two auxiliary diesel generators, each of 257 kW output and a 90 kW emergency diesel generator fitted with auto-start in case of electrical power failure.

The ship's complement consisted of the master, chief engineer, mate, three able seamen, an ordinary seaman, an oiler and a cook. The master was a German national and the chief engineer a Romanian national. The rest of the ship's complement was made up of Ukrainian nationals. The chief engineer had joined the vessel one month earlier, for the first time both with the ship and the company.

The master, mate and a qualified able seaman maintained bridge watches on a 'one in three' routine. The engine room is usually unmanned outside normal working hours.

At the time of the incident all ship's certificates required under international shipping conventions were valid. The vessel was manned in accordance with a Safe Manning Certificate as issued by the Department of Marine Services and Merchant Shipping of the government of Antigua and Barbuda. *ANL Purpose*, as a general cargo vessel, was not required to hold an International Safety Management Certificate until July 2002, however the owner had commenced implementing some of the ISM documentation on board.

---

1 In January 2003, the vessel was sold to Musca Shipping, Denmark, and now trades as the *Karen Danielsen*, under the Bahamas flag.

With effect from 11 November 2000, *ANL Purpose* was on time charter to the German company BBC Chartering and Logistics GmbH & Company KG, from the owner, Foroohari Schiffahrts KG. From 2 March 2001, at Singapore, BBC sub-chartered it on an extendable time charter to the Australian company, ANL Container Line Pty Ltd.

According to the German Flag Act, (Flaggenrechtsgesetz), permission to fly a foreign flag for a certain period can be granted to a German ship which is chartered for a minimum of one year by an operator who is not a German national or who has no German residence. Such a ship (on bareboat charter) may remain registered on the German Register of Ships in accordance with the Liens and Mortgage Convention. Thus, *ANL Purpose*, although flying the flag of Antigua and Barbuda, remained registered in the port of Hamburg.

Narrative

On 3 August 2001, *ANL Purpose* was lying in the port of Lae, Papua New Guinea, loading containers for the ports of Melbourne, Sydney and Brisbane. The cargo consisted mainly of tea and coffee. At 1345, cargo operations were completed and the vessel sailed for Melbourne at 1450 that same afternoon, disembarking the pilot at 1500.

The first three days of the voyage passed without incident. The weather was fair, the winds no stronger than force three or four, from a south-easterly direction.

At 2100 on Monday, 6 August, *ANL Purpose* was at the position 18° 23.6' S, 152° 54.3' E and making good 11 knots on a course of 74° (T). The nearest land was Marion Reef, 45 nautical miles to the south west and Lihou Reef, some 76 nautical miles to the north west. The master was on watch on the bridge and the chief engineer was in his cabin, reading, when an engine alarm annunciated.

The breakdown

The chief engineer went below, to the engine room, where he observed that the activated alarm was from the main engine oil mist detector. As programmed in the case of such an alarm, the main engine had automatically reduced in load. His first thoughts were that the photocell in the oil mist detector may have become obscured and needed cleaning – a not uncommon occurrence. He started to open the oil mist detector unit at the port side of the engine, but, as he did so, loud noises began emanating from no. 4 unit. He started to make for the engine control room to advise the bridge but, seconds later, he decided to first stop the engine at the local control position to avert any subsequent engine damage. The noises from the engine had also been heard by the master on the bridge.

With the main engine, and hence the shaft generator, stopped, there was a brief blackout until the emergency generator started automatically and came on line, restoring the vessel's lighting. The chief engineer started one of the diesel generators in order to restore electrical power to the rest of the ship's systems, but an alarm for low cooling water level activated. Its cooling water supply is arranged in common with that of the main engine. After isolating the cooling water from the main engine he topped up the cooling water expansion tank, then called the master and advised him that there was a problem with the main engine. On the bridge, the master switched on the 'not under command' lights.

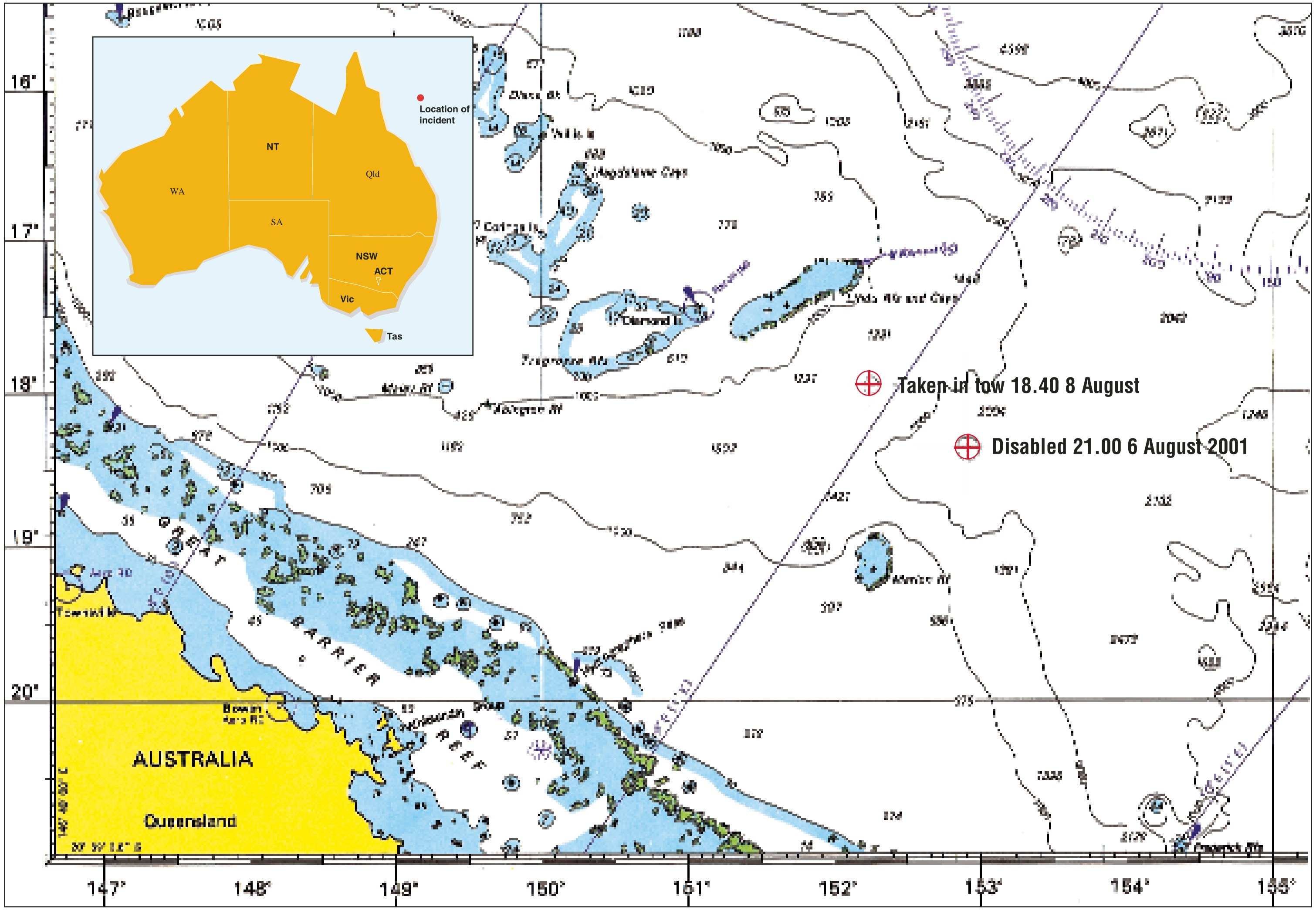
Damage assessment

Looking at no. 4 unit of the main engine, the chief engineer had noticed that the rocker cover had been damaged – the aluminium casting had split across the middle. Removing the cover, he found that the rockers were held onto the cylinder head by only two, bent, studs. Another stud was broken and the fourth had been stripped out of the head. Thinking that this was the only problem, he commenced removing the rocker gear from the cylinder head. At about that time, the master came below to look at the damage.

As the chief engineer was removing the rocker gear, he instructed the oiler to sound the lubricating oil sump tank. The oiler reported that the sump tank was over-filled.

The chief engineer opened the port crankcase door on no. 4 unit, whereupon he saw that both the piston and the cylinder liner had shattered into numerous small pieces and the engine sump was full of debris. He informed the master, who had returned to the bridge, of this discovery, then began removing the cylinder head to further ascertain the extent of the damage. At 2126, the master contacted the vessel's manager in Germany, by email, advising him of the breakdown, and that further information would

Figure 1:
Extract from chart Aus 4604 showing position of *ANL Purpose* when the vessel became disabled on 6 August and position of rendezvous with the tug *Giru* on 8 August



follow. He received instructions to isolate no. 4 unit, and to proceed on five cylinders. Further dismantling of the unit revealed the remains of the piston, (only the crown) jammed solidly at an angle in the remains of the cylinder liner (the top 150 mm, forming the collar).

When the top of the cylinder liner had been removed, a hole, about 14 cms in diameter, was found in the engine entablature passing from the jacket cooling water space through to the charge-air manifold. The damage observed convinced the chief engineer that it would not be possible for the ship's staff to carry out repairs sufficient to restart the main engine on five cylinders and, at 2215, he advised the master accordingly. He also asked the master for assistance from the deck crew to remove the remaining components of no. 4 unit.

The tow

At 2230, the master, using Satcom C, informed the vessel's owner and AusSAR (the Australian Search and Rescue Co-ordination Centre) of the vessel's predicament. *ANL Purpose* was drifting in a mainly north-westerly direction at a speed of approximately 1.3 knots. It was, however, in no immediate danger. AusSAR instructed the master to keep the Centre advised of the vessel's situation every four hours.

At 0252 the following morning, 7 August, the master received a message from the vessel's owner informing him that the tug *Giru* would leave Townsville at 0700 that morning to render assistance.

ANL Purpose continued to drift in a west-north-westerly direction at an average speed of 1.2 knots. The seas remained smooth or slight, from the south east, with a wind of force two to three. There appeared to be no danger of grounding on Lihou Reefs before 10 August.

At 1654 on 8 August, the tug *Giru* made a rendezvous with the ship which had, by that time, drifted to a position of 17°59.1' S, 152°15.1' E. A heavy bridle was passed through the forward centre lead on *ANL Purpose* and, at 1840, the tow to Brisbane started. The tow, at a speed of 7 to 7½ knots, proceeded in good weather with south-easterly winds no greater than force 4.

A plan had been made for the Brisbane-based tug *Bulimba* to take over the tow from the Townsville-based *Giru* in the shelter of Saumarez Reef and, at 1115 on 10 August in position 21°51.1' S, 153° 28.6' E, the tow was transferred to *Bulimba*. The tow to Brisbane was completed in good weather with light south-easterly winds and seas.

At 0600 on 12 August, *ANL Purpose* arrived at the Brisbane pilot boarding ground and the towing gear was reduced to a length suitable for passage up the Brisbane River. The pilot boarded at 0638. At 1145 the tow was further shortened to a harbour tow and, at 1210 a second tug, *Willara,* made fast to the stern of *ANL Purpose*.

At 1415, *ANL Purpose* was berthed alongside the repair wharf of Forgacs Cairncross shipyard in the Brisbane River where it remained for several weeks undergoing repairs to the main engine.

Comment and analysis

The Wärtsilä Vasa GR32 engine

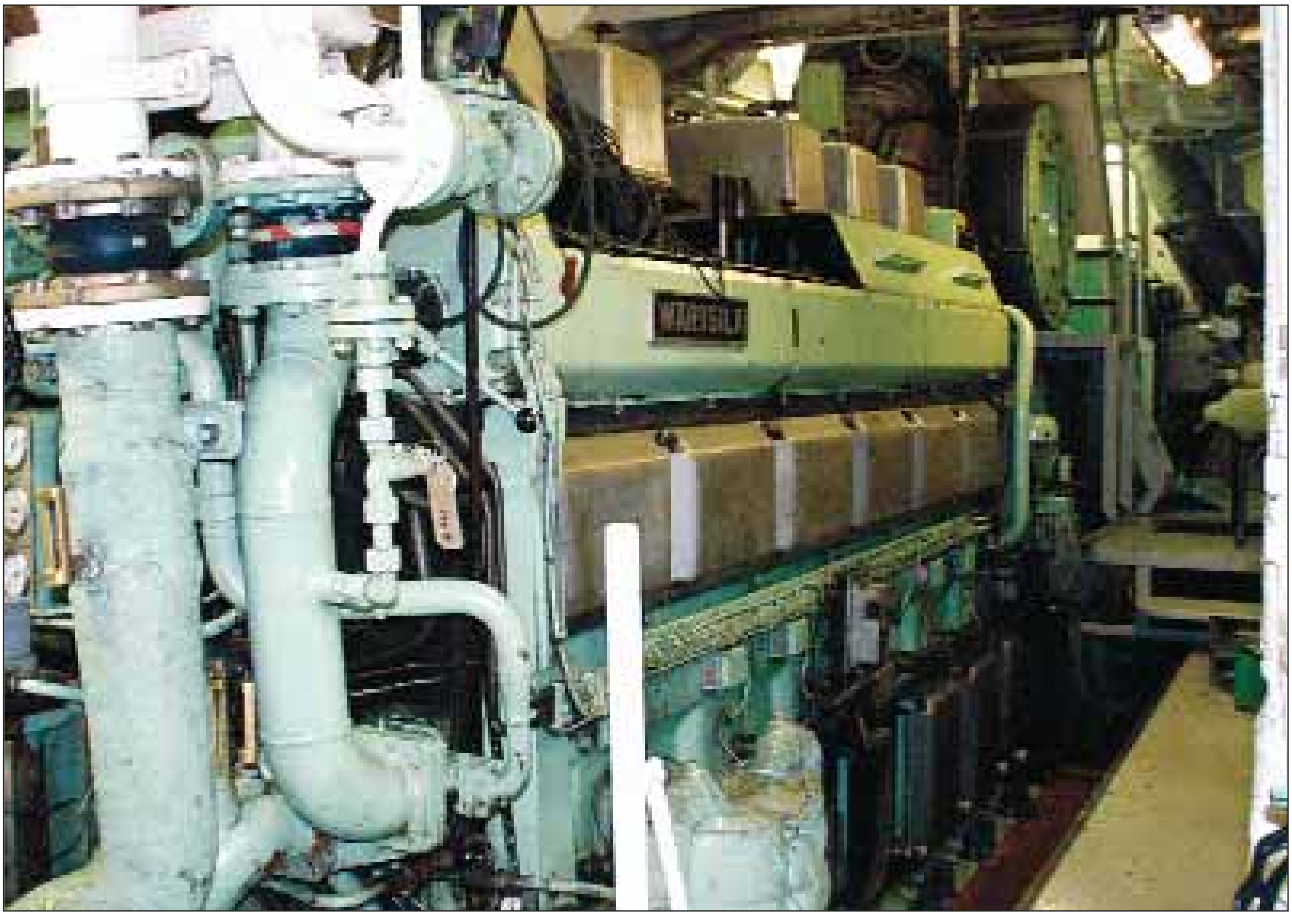
The main engine of *ANL Purpose* is a Wärtsilä Vasa GR32, 6-cylinder, in-line, four-stroke diesel engine of 320 mm bore and 350 mm stroke. It is a turbocharged, intercooled engine with direct fuel injection, developing 1495 kW (2032 shp) at a constant speed of 720 rpm, driving a single shaft with a controllable-pitch propeller. The shaft is fitted with a shaft generator.

The engine block is a one-piece grey iron casting with the charge-air receiver and cooling water header integral with the casting. Cylinder liners, which seat directly on top of the entablature, are grey cast iron designed with high collars, drilled with cooling holes, and fitted at the top with an anti-polishing ring. Sealing at the top is metal to metal, with the cooling water space sealed by two O-rings on the bottom of the liner.

The main bearings are hanging, with the bearing caps being each supported by two hydraulically tensioned main bearing studs. The crankshaft, balanced with counterweights, is a one-piece chrome-molybdenum steel forging with bearing surfaces hardened to 50-60 Rockwell$_c$.

The connecting rods are drop-forged with a split bottom-end with serrated mating faces. The bottom-end bearing, fitted with tri-metal bearing shells, is stepped to achieve large bearing surfaces. The connecting rods fitted in *ANL Purpose* were of the earlier type having an oval cross-sectional profile, indicating that these

FIGURE 3:
Main engine of *ANL Purpose* – Wärtsilä Vasa GR32 four-stroke diesel



were the original rods as the later type have an H-section profile.

Pistons

No record was available which indicated that the pistons in *ANL Purpose*, at the time of the engine failure, were other than those originally fitted when the engine was built in 1985. These were of one-piece (or monobloc) construction in nodular cast iron and fitted with two compression rings and two oil scraper rings. Not long after *ANL Purpose* was built, however, this monobloc piston design was superseded, in Wärtsilä Vasa 32 engines, by composite pistons having a nodular cast iron skirt and a forged steel crown.

Lubricating oil supply

Lubrication for the engine is supplied by an engine-driven lubricating oil pump. An electrically driven pre-lubricating oil pump is also provided, arranged in parallel with the engine-driven pump. Oil from the main pump passes through an oil cooler and a thermostatically controlled bypass valve to duplex oil filters. From the filters, the oil passes to a main distribution pipe running along the engine inside the sump.

From the main distribution pipe, the oil passes up through the hydraulic jacks (used when lifting the main bearing caps into position) and into the main bearings. From the main bearings it passes through drillings in the crankshaft to the bottom-end bearings.

The oil passes through holes in the crankpins and through rows of holes in the bottom-end bearing shells to the connecting rods. It flows up the centre of the connecting rods and then enters the pistons as piston cooling oil. At the same time, it provides lubrication for the gudgeon pins. The interior spaces of the pistons are designed to provide the maximum 'cocktail shaker' effect and hence maximum piston cooling.

The Wärtsilä Vasa 32 is a dry-sump engine and piston skirt lubrication is provided by a patented Wärtsilä skirt lubrication system in which oil passes from the interior of the piston through the ring grooves.

Fuel and lubricating oil

The heavy fuel oil in use for the main engine at the time of the incident was supplied by Caltex Australia and bunkered in Sydney on 23 July 2001. It was a blended fuel oil of density 0.982 and with a viscosity of 168.5 c/stokes. There was no evidence that the quality of the fuel had played any part in the failure of the engine.

The lubricating oil circulating in the main engine, Shell Argina T30, had last been tested by a Shell laboratory in January 2001. The laboratory report indicated that the oil was fit for further use and that the engine appeared to be operating normally with no indications of abnormal wear or component stress. Eight days after the engine failure, another sample was submitted to the Shell laboratory and a similar result obtained.

There was no evidence that the quality of the lubricating oil in use had played any part in the failure of the engine. The engine room logbook showed that there had been satisfactory oil pressure during the period leading up to the engine failure. This, together with the absence of any "low lubricating oil pressure" alarms, would preclude low system oil pressure as having been a contributing factor.

Investigation

By the time *ANL Purpose* arrived at the Cairncross shipyard, and the ATSB started an investigation into the engine failure, no. 4 unit of the main engine had been completely dismantled. Much of the debris from the engine sump, which consisted mainly of fragments of the piston and the cylinder liner, had been moved, in plastic garbage bags, to the upper deck. These were examined, as were the remains of the cylinder liner, with the piston crown still jammed in it, the connecting rod and bottom-end bearing cap, the two bottom-end studs, and the bottom-end bearing. The cylinder head and components of the valve gear were later examined at the workshops of Wärtsilä-NSD in Sydney.

The bottom-end bearing shells, upper bottom-end stud and fragments of piston skirt and cylinder liner were again examined at the engineering failure analysis laboratory of the ATSB in Canberra. The components were then returned to the ship to enable a further investigation to be carried out by ETRS, Brisbane, on behalf of the Salvage Association.

Interviews were conducted with the master and the chief engineer and, in addition to the examination of the physical components of the engine removed from no. 4 unit, the ship's certification, other documentation and the main engine maintenance records were also examined. These maintenance records consisted, almost exclusively, of copies of a monthly running sheet, forwarded each month to the owner.

Engine damage

At the time of the failure, the main engine of *ANL Purpose* had accumulated a total of 87 316 running hours.

Initially, the most obvious damage was to the piston and cylinder liner. The piston skirt had shattered into numerous small pieces, as had the cylinder liner below the collar. The fragments of piston skirt and cylinder liner showed clear evidence of heating, scoring and seizure.

The connecting rod had suffered damage in the form of numerous gouges and indentations inflicted during the revolutions made by the engine between the piston failure and the time it was stopped by the chief engineer. The bearing cap had suffered little damage, but it was evident that the bearing shells had moved some 10-20 mm in an axial direction out of the bearing, one side having moved further out than the other. The edge of the bearing shells had been in contact with the crankshaft web, whereupon they had been splayed back with a radius matching that of the fillet at the base of the web.

The lower face of the cylinder head had suffered relatively little damage, a few dents, but two of the valves had bent stems and one of the holes for the studs securing the rocker-gear had a stripped thread.

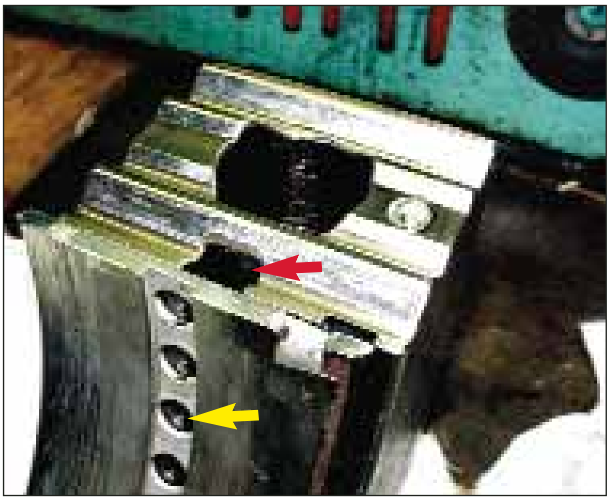
The crankpin and webs of the crankshaft at no. 4 unit had suffered no significant damage. However, in addition to the destruction of the piston and cylinder liner and the damage sustained by the connecting rod and bottom-end bearing, serious damage had been sustained by the engine block.

When the cylinder head and the top, remaining, part of the liner had been removed at sea, a hole, about 14 cms in diameter, was found in the engine entablature passing from the jacket cooling water space through to the charge-air

FIGURE 4:
Top of cylinder liner with remains of piston crown jammed within it

FIGURE 5:
Front edge of upper half of bottom-end bearing shell splayed back in way of crank web

FIGURE 6:
Bottom-end bearing cap and shell, showing relative movement between oil gallery (red arrow) and oil holes in shell (yellow arrow)



manifold. In addition, but less obvious, was a vertical crack extending through a longitudinal stiffening web of the engine block casting. This crack, which was found later when a more thorough examination of the damage was carried out in Brisbane, was just above the no. 4 unit starboard crankcase door. A number of options for repairing this crack were later considered, such as by the 'Metalock' process, but none was likely to prove satisfactory and it was eventually decided that there was no option but to replace the engine block. This was a relatively major undertaking which required shipping a new block from the engine manufacturer's works in Vasa, Finland and cutting away part of the deck above the engine room to enable the damaged block to be removed and the new one fitted.

Later examination of the pistons from the remaining five units, including thorough crack-detection testing, at the Forgacs Cairncross Dockyard, showed that the pistons from nos.1 and 2 units displayed significant indications of fatigue cracking in the area of the gudgeon-pin boss. When the fragments of piston from no. 4 unit underwent a further metallurgical examination by consultants on behalf of the Salvage Association, it was found that no. 4 piston, also, had suffered from fatigue cracking

FIGURE 7:
Hole through engine entablature from jacket cooling water to charge air spaces

FIGURE 8:
Crack (enhanced) through stiffening web in entablature at no. 4 unit

FIGURE 9:
Fatigue cracking detected in no.1 piston (left) and no.2 piston (right) in the gudgeon pin support webs of both pistons
(Forgacs Engineering Pty Ltd.)

in the vicinity of the gudgeon pin boss and its supporting webs.

Wärtsilä technical bulletins and service letters

Over the years since the introduction of the Wärtsilä VASA 32 engine in its different configurations, a number of Wärtsilä Service Letters and Technical Bulletins were issued relating to the operation and maintenance of the engine. The investigation found that three of these related to the failure of the main engine of *ANL Purpose*. These were:

1. Wärtsilä Operating Instructions (Document no. 2211Q014011) issued on 22 October 1987. "Assembly of bearings". This document contained a warning:

   A correct assembly of the main and big end bearing shells is of the utmost importance for safe operation of the engine.

   With this Service Letter we want to draw attention to the fact that it is possible to get an obliquity of the bearing shells in the main bearing or big end bearing if they are not carefully installed. Tests have shown that the bearing shells may not align when the bearing halves are put together and the screws are tightened. This means that the bearing shells have to be carefully put into place before assembly of the bearing and also checked visually after tightening of the bearing screws.

2. Wärtsilä Service Letter (Document no. 3204N026GB) dated 25 November 1997 "Main components' maintenance intervals for VASA 32, 32LN and 32 GD"

   This document contains general recommendations on maintenance intervals for the main components of the above engines. The 11 page document, containing mostly tables, shows the relationship between maintenance intervals, application of the engine (loading) and fuel quality. The tables are divided into two groups, one for engines without, and those fitted with, anti-polishing rings.

3. Four Wärtsilä-NSD Measurement Record sheets (Documents 3211V014GB, 3211V015GB, 3211V016GB, and WV11V056GB) issued on 20 May 1999.

These sheets provide information on the measurement of major engine components, such as the positions at which measurements are to be taken, normal tolerances and wear limits. They also contain tables in which the results of measurements taken at inspections and surveys are to be recorded.

The main engine of *ANL Purpose* was still fitted with the connecting rods and one-piece or 'monobloc' pistons from the original engine build. All documentation issued by Wärtsilä and relating to maintenance and overhaul of pistons referred to the later, two-piece, pistons with forged steel crown and cast iron skirt. A service letter from Wärtsilä, issued on 13 June 1994, relating to overhaul of these later pistons contained an opening paragraph:

> Most of the VASA 32 engines in operation are fitted with composite type pistons, made by either Mahle or Kolbenschmidt. For these pistons it is necessary to make more extensive inspections after exceeding 24,000 running hours.

It contained detailed instructions on the overhaul and inspection of these pistons. Particular reference is made to thorough crack detection, especially around the upper part of the piston skirt and to the gudgeon pin bore with its supports to the upper part and to the circumferential part of the skirt. The service letter, however, made no reference to the older pistons as fitted to the engine in *ANL Purpose*, even though the internal construction of the skirt, around the gudgeon pin bore, was very similar and of the same material. It is also susceptible to cracking as this incident, and the subsequent examination of the pistons from nos.1 and 2 units, showed.

According to Wärtsilä's instructions on the maintenance intervals for the main components, these pistons, even under the most favourable operating conditions, were recommended for thorough overhaul, including crack-detection, at intervals not exceeding 20 000 running hours, and replacement at intervals not exceeding 40 000 running hours. These figures were for engines without anti-polishing rings. For engines with anti-polishing rings, these running hours were extended to 24 000 and 48 000 respectively.

ANL Purpose had run for 37 369 hours, to January 1993, without anti-polishing rings and for a further 49 947 hours (to a total of 87 316 hours) with anti-polishing rings. Throughout this extended period, no piston replacement or thorough piston examination (including crack-detection) had taken place.

Wärtsilä, invited to comment on these running hours, supplied the maintenance interval instructions relating to the composite pistons, but also stated:

> Due to the age of these pistons, the prudent owner should have checked the pistons thoroughly.

and:

> …would expect the prudent owner to probably crack test at 64 000 hours.

However, Wärtsilä had issued no documentary information relating to reducing overhaul intervals or crack detecting pistons of the earlier 'monobloc' type.

Over recent decades there has been a great increase in the frequency with which vessels change owner, name, flag or class. Consequently, many manufacturers of ship's machinery, or other equipment, experience difficulty in ensuring that relevant documentation such as service letters and technical bulletins continue to reach all vessels fitted with their equipment. From the time it was built, *ANL Purpose* had undergone six changes of name (and there have been a further two changes since the incident) and it had changed flag twice (once more since the incident).

Failure analysis

A Technical Analysis report on the engine failure is contained at Attachment 1.

The Wärtsilä VASA 32 engine connecting rod bottom-end bearing shells can, without careful installation and checking, be mis-aligned on assembly of the bottom-end. This is borne out by the Wärtsilä 'Operating Instructions' of October 1987 and the finding made by a previous chief engineer, and recorded in the ship's Continuous Survey of Machinery, a year before this incident when he surveyed no. 3 unit.

When the bottom-end of no. 4 unit was examined as part of this investigation, it was found that the bearing shells had moved forward out of the bottom-end partially obstructing the oil flow into the oil gallery around the bottom-end of the connecting rod. In addition, it was found that they had moved out at an angle being displaced approximately 10 mm on one side and 20 mm on the other. The locating tangs on the shells were not distorted but neatly folded inwards, a further indication that the bearing cap may have been tightened with the shells in an incorrect position during assembly of the bottom-end at the last overhaul in May 1999 at 2195 running hours. Incorrect assembly would have resulted in the loss of the 'crush' force which retains the bearing shells in the correct position. This, in turn, would allow the bearing shell halves to work their way very slowly out of the correct position, over the intervening period before the failure.

On 30 June 2000, just over a year before the incident, a report, which is significant to this investigation, was made by a previous chief engineer, as part of the Continuous Survey of Machinery. That report related to the survey of the bottom-end bearing in no. 3 unit. When opened up, it was found that both shell halves were '…slightly damaged because the bearing had not been assembled in the correct position'.

Another possibility considered and put forward in the ETRS analysis was that the bearing shells had been driven axially out of the bottom-end by the flailing connecting rod immediately after the disintegration of the piston. On neither bearing shell, however, did the back face show any witness marks consistent with an impact force from the loosening connecting rod or bearing cap which could have driven the shells out in the axial direction with sufficient force to splay the leading edges back into the fillet at the base of the crankshaft web. In addition, after the failure, the bearing cap was still in position with one bottom-end bolt still tight, even though the nut on the other had loosened. For these reasons, the possibility of the shells having moved axially out of the bottom-end during the final moments of the engine failure on 6 August is considered most unlikely.

The piston and cylinder liner fragments from no. 4 unit showed distinct evidence of overheating, scoring and partial seizure. This would be consistent with the piston temperature having increased due to a restriction of its cooling oil flow through the connecting rod, caused by movement of the upper bearing shell. The alarm from the oil mist detector was the first indication of a problem and this, again, would support the proposition that heat, and consequently oil mist, was being generated by a partial piston seizure.

In the metallurgical examination of the piston fragments, conducted by ETRS, consultants on behalf of the Salvage Association, there was clear evidence of cracking in the nodular cast iron of the piston, particularly around the supports for the gudgeon pin bore. Similar cracking was found in the pistons removed from nos. 1 and 2 units.

Such cracking would have seriously weakened the piston, to the point where the extra loading on the gudgeon pin, caused by partial seizure of the piston, and hence on the supports for its bore, would have caused the piston to break up.

In a submission on the draft report received from ETRS, the opinion was expressed that the ATSB report did not give sufficient weight to the cracking found in the failed piston from no. 4 unit as well at the pistons from nos.1 & 2 units. ETRS concluded that there was ample cause for failure of the engine through cracks in the piston. It was stated that cracking in no. 4 piston had reached such an advanced stage that the piston would have broken up whether the oil flow was constricted or not. It was also noted that, since the cracks intersected the vertical oil holes between the gudgeon pin and the piston crown, oil could have been lost at that point, leading to the indications of piston seizure.

ETRS also disagreed with the possibility that the bottom-end bearing shells had been incorrectly assembled and concluded that their displacement had been caused by asymmetric forces on the big end after the gudgeon pin broke out of the failed piston. It was stated that the angle of the tangs on the bearing shells indicated progressive inward pressure due to gradual forward movement (a conclusion in accord with the ATSB analysis). It was also felt that overheating of the piston due to restriction of the oil flow because of this movement was only one way in which oil flow into the piston could be reduced.

It is not possible to positively identify the exact reason for the failure. There is no doubt that prior fatigue cracking of the piston in the vicinity of the gudgeon pin was a significant factor. Nevertheless, for those reasons outlined in both the body of the ATSB report and the attached Technical Analysis, the Bureau remains of the opinion that the most likely initiating factor for the failure was piston seizure (as indicated by the oil mist detector alarm). This seizure, brought on by a reduction in piston cooling oil flow, was followed by failure of the piston at the area of pre-existing fatigue cracking. The reduction in oil flow was due to a very gradual axial movement of the bearing shells – probably, in turn, due to incorrect assembly at the last overhaul, 2195 running hours earlier.

Engine maintenance

Those records relating to maintenance of the main engine on board the vessel, and made available to the investigation, consisted of the Germanischer Lloyd class survey record for Continuous Survey of Machinery, the engine room log book, monthly engine condition report sheets, bunker receipts and analyses of lubricating oil. The last of these was conducted eight days after the incident. The monthly condition report sheets, returned to the office of Foroohari Schiffarts KG each month, contained details of engine and component running hours, fuel and oil consumption and notes of routine maintenance items carried out during the month.

Apart from these items there were no formal maintenance records kept on board and no records of major overhauls or repairs were available. The classification society record of survey, issued on 5 July 2000, showed that no. 4 cylinder, piston and connecting rod had last been surveyed by a previous chief engineer in May 1999, since which time it had accumulated 2 195 running hours.

Further information on major work, which could have been carried out on the engine during previous years, by the engine builders or their representatives, was sought from the engine manufacturers through Wärtsilä-NSD, Sydney. In regard to major work, this revealed that the engine had had a major overhaul in January 1993, at 37 369 running hours, when the cylinder liners were modified to an 'anti-polishing ring' type , and another major overhaul in May 1995, at 47 795 running hours. In June 2000 the main bearings and vibration damper were replaced by the engine manufacturers. No further information was available.

Only one of the Wärtsilä service documents relating to this engine was found on board *ANL Purpose*. Ironically, that was the warning about correct assembly of the bearings. (No. 1 on page 13). This service document was found as a loose sheet amongst piles of papers in the drawers in the chief engineer's cabin. The previous chief engineer, who surveyed the bottom-end of no. 4 unit, in May 1999, may not have been aware of its existence.

No completed Wärtsilä measurement record sheets (as in 3, on page 13) were available to the investigation on board the vessel. Indeed, there were few formal maintenance record sheets of any kind.

Overall, the standard of record keeping in relation to maintenance of the main engine was less than adequate. Apart from the Germanischer Lloyd survey record and copies of the monthly running sheets which had been forwarded to the owners, nearly all other documentation was in the form of loose sheets, notes, letters etc. in various drawers and cupboards around the chief engineer's cabin.

---

2 A ring, with a finely chamfered inside surface, fitted as an insert in the top of the cylinder liner to reduce lubricating oil consumption and, at the same time, to reduce cylinder liner/piston crown wear.

Conclusions

These conclusions identify the different factors contributing to the engine damage sustained by *ANL Purpose* and should not be read as apportioning blame or liability to any particular individual or organisation.

1. The proximate cause of the failure of the main engine of *ANL Purpose* was the partial seizure and consequent break-up of the piston in no. 4 unit.
2. The partial seizure was brought on by a reduction in piston cooling oil supply caused by the axial movement of the bottom-end bearing shells, which partially obscured the oil passages in the lower end of the connecting rod.
3. The manner in which the bottom-end bearing shells had moved and the state of the locating tangs, suggests that they had been fitted incorrectly, probably in the manner cautioned against in the Wärtsilä service letter (Document no. 2211Q014011) issued on 22 October 1987.
4. The piston in no. 4 unit contained pre-existing fatigue cracks in the gudgeon pin support webs and at the base of no. 4 ring support groove. These cracks weakened the piston to the point where the additional loading on the gudgeon pin, caused by the partial seizure, was sufficient to cause its disintegration.
5. The pistons in service at the time of the incident were those originally fitted to the engine when built, in 1985, and had accumulated 87 316 running hours without replacement and there was no evidence of their having undergone crack detection at any time.
6. Although Wärtsilä had issued a service letter advising owners to carry out more extensive testing of the later, two-piece pistons, at overhauls, there was no advice regarding the earlier, monobloc, pistons.
7. The standard of maintenance records aboard *ANL Purpose* was less than adequate. In particular, the service letter from Wärtsilä warning of incorrect assembly of the bottom-end bearing was in an obscure position amongst a pile of papers in a drawer and may not have been evident to a previous chief engineer who overhauled the bottom-end of no. 4 unit in May 1999.

Recommendations

MR 20030024

That Wärtsilä-NSD consider issuing a service letter to owners of VASA 32 engines advising that the Wärtsilä Service Letter (Document no. 3204N026GB) dated 25 November 1997 'Main components' maintenance intervals for VASA 32, 32LN and 32 GD' should also apply to any one-piece, or 'monobloc' pistons still in service or provide other appropriate service guidance.

Submissions

Under sub-regulation 16(3) of the Navigation (Marine Casualty) Regulations, if a report, or part of a report, relates to a person's affairs to a material extent, the Inspector must, if it is reasonable to do so, give that person a copy of the report or the relevant part of the report. Sub-regulation 16(4) provides that such a person may provide written comments or information relating to the report.

The final draft of the report was sent to the following:

Foroohari Schiffahrts KG

The master and the chief engineer of *ANL Purpose*

Wärtsilä-NSD

ETRS (HRL Materials Consulting Group)

Australian Maritime Safety Authority

A submission was received from ETRS and is discussed in the text of the report.

ANL Purpose

IMO Number	8500070
Flag	Antigua & Barbuda
Classification Society	Germanischer Lloyd
Ship Type	General cargo
Builder	J.J. Sietas KG Schifftswerft GmbH & Co
Year Built	1985
Owner	Foroohari Schiffahrts KG
Ship Manager	Foroohari Schiffahrts KG
Gross Tonnage	3120
Net Tonnage	1632
Summer deadweight	3650 tonnes
Summer draught	6.05 m
Length overall	88.6 m
Breadth	15.68 m
Moulded depth	8.31 m
Engine	6 cylinder Wärtsilä GR 32 four-stroke diesel
Power	1495 kW
Crew	9

Department of Transport and Regional Services

Australian Transport Safety Bureau

TECHNICAL ANALYSIS REPORT

Report No. 29/02 Draft 3

File No. B2001/0398

Review of Information relating to the Failure of the Main Engine of the General Cargo Vessel *ANL Purpose*, 6 August 2001

Prepared by: NR Blyth
Senior Transport Safety Investigator
Technical Analysis

CONTENTS

EXECUTIVE SUMMARY

Following the catastrophic failure of the main engine from the vessel *ANL Purpose,* a series of examinations were undertaken by various parties to investigate the breakdown. Subsequently, a review of the information available from these investigations was undertaken by the Australian Transport Safety Bureau to obtain a greater understanding of the events associated with the engine failure and to determine where possible, the significant factors that lead to the occurrence.

Principally, the engine failure aboard the *ANL Purpose* occurred as a result of the mechanical failure and break-up of one of the engine's six pistons. Associated with the failure was the axial movement of the connecting rod big-end bearing shells. This shell movement had partially obstructed the connecting rod oil galleries and restricted the flow of lubricating and cooling oil into the piston. While it was not possible to ascertain when the movement of the bearing shells had occurred, it was noted that the engine type had a history of bearing mis-installation, which could have pre-disposed the bearings to movement if the mis-installation had occurred on the engine in question. The restriction of cooling oil flow to the pistons could lead to overheating and binding within the cylinders. Some evidence of this was observed on the piston and cylinder fragments.

The review also found that the engine type had a susceptibility to cracking of the piston body, particularly in the more highly stressed upper areas. Evidence of pre-existing fatigue cracking was found on the failed piston and two other units from the same engine. The growth of cracking would have progressively reduced the strength of the pistons, rendering them increasingly susceptible to failure. The risk of failure would be further exacerbated under overload conditions, such as would be sustained if the pistons overheated and began to bind or experience higher cylinder friction levels.

1. FACTUAL INFORMATION

1.1. Examination brief

On the evening of August 6, 2001, the main engine of the cargo vessel *ANL Purpose* sustained extensive damage as a result of an internal mechanical failure. The damage was such that the engine was incapable of further operation, rendering the vessel without propulsion and necessitating that it be towed to a Brisbane shipyard where the damage could be assessed and repaired.

During the period when the engine was undergoing repairs, a number of parties (including the Australian Transport Safety Bureau) commenced investigations to determine the nature and probable causes of the failure. This report was prepared to review these investigations and discuss the potential modes of failure that the investigation findings revealed.

The following sources of information were used to compile this review:

ANL Purpose Chief Engineer's report, dated 12-8-01
ETRS Pty Ltd Investigation report No: QRH01-4377
Wartsila Diesel Australia Service Report, dated 24-9-01
Forgacs Cairncross Dockyard NDT report, Job No: 6640/309
ATSB laboratory examination observations and findings
ANL Purpose service history reports, April '01 – July '01

Additional documents were also referred to where they had relevance to the occurrence – these were individually referenced in the text.

1.2. Summary of the failure

In the statement made by the ship's engineer, the first sign of a problem with the main engine was the sounding of an alarm that indicated excessive levels of oil mist within the engine crankcase. It was during the ensuing period when the alarm was being investigated that the engineer heard a loud, abnormal noise from the engine. Electing to immediately stop the engine from a local control panel, the engineer noted that the number-four cylinder rocker cover had sustained internal impact damage and had torn open. A more detailed examination that followed showed that the piston and liner from the number-four cylinder had broken into multiple fragments – many of which had fallen into the engine crankcase. A large hole was found within the cylinder block and the upper section of the piston had become lodged within the top of the cylinder liner. Checks of the connecting rod bolts found both to be significantly below the required tension, with one nut only hand-tight.

1.3. Engine details and history

The failed main engine from *ANL Purpose* was a Wartsila Diesel 'VASA 6GR 32' six-cylinder diesel engine, serial number 3337. The engine operated at a nominal speed of around 720 revolutions per minute and had a rated power output of 1,495 kW. At the time of failure, the engine was operating on Caltex 100 cSt heavy fuel oil (HFO).

Maintenance records showed the engine to have accumulated a total of 87,316 operating hours at the time of failure. July 2001 records for the six engine pistons noted a range of times since overhaul of 1,859 to 3,124 hours, with the failed number-four piston listed at 2,195 hours. The pistons were understood to be the original from the engine and thus would have had a total time-in-service equating to the total engine hours (87,316). The installed pistons were a one-piece 'monobloc' design. That design had been superseded by a two-section composite construction that allowed the crown to be separated from the piston skirt.

1.4. Overhaul requirements

In Service Letter 3204N026GB, dated 25 November 1997, the engine manufacturer recommended a range of overhaul and replacement periods for the piston components, based upon the engine duty, the type of fuel and the presence or otherwise of a cylinder anti-polishing ring. That information, however, was supplied by the manufacturer as being applicable to the later composite (two-piece) piston types. Based on the use of the Caltex 100 cSt fuel oil and the presence of an anti-polishing ring, the recommended time between piston overhauls was 12,000 hours, with a replacement life limit of 48,000 hours. In Service Letter 32115025GB (23 June 1994), the manufacturer stated that at an operating age of 24,000 hours and for every overhaul thereafter, a series of tests and inspections should be carried out on the piston units. Those tests included crack detection of the piston crown and the upper part of the skirt, including the gudgeon pin bore and supports. Additionally, commentary from the engine manufacturer suggested that the pistons should have been thoroughly inspected and crack-tested at a life of 64,000 hours. During the course of this investigation there was no evidence found to indicate that crack detection had been carried out during the last overhaul of the cylinder assemblies, or at any time previously.

Replacement of the connecting rod bolts was recommended every 24,000 hours of operation and replacement of the connecting rod bearing shells was recommended at each overhaul (12,000 – 16,000 hours). A Wartsila Diesel service letter (Ref. PG22/32, 22-10-1987) for the VASA type 32 engines warns of the risk of incorrect installation of the connecting rod bearing shells and states that the bearing shells may not align when the bearing halves are assembled. Specific checks were required after tensioning the connecting rod bolts to ensure the bearing shells were correctly located. A survey report prepared on 30 June 2000 indicated that bearing misassembly within the number-three crank-pin connection of the *ANL Purpose's* engine had resulted in damage to the working surfaces of both bearing shells.

1.5. Pistons and cylinders

Initial reports from the ship's engineer and subsequent laboratory examinations conducted by ETRS Pty Ltd and the Australian Transport Safety Bureau found that the number-four piston and cylinder (both manufactured from spheroidal graphite cast-iron) had broken up while in operation. Fragments of the piston skirt and the cylinder showed evidence of heavy scoring and frictional overheating of the running surfaces (figures 1 & 2). Evidence of pre-existing cracking was found within the fragments of the piston that made up the gudgeon pin support pillars and the base of the number-four ring groove. When the other five pistons from the engine were inspected using crack detection techniques, two of the units also revealed significant crack indications around the gudgeon lateral supports and pillars. Confirmed as fatigue cracking by subsequent fracture surface examination, the general nature of the cracking was very similar to that shown by the fractured remnants of the number-four piston.

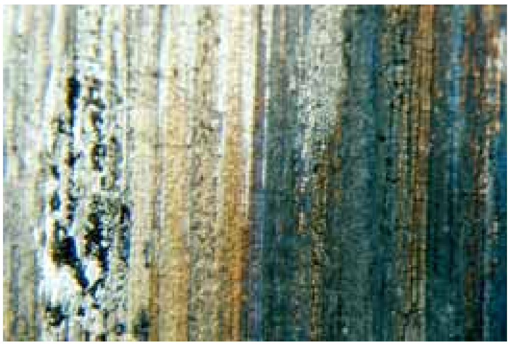


Figure 1. External surface of a fragment of the piston skirt – shows appreciable axial scoring and frictional heat tinting.

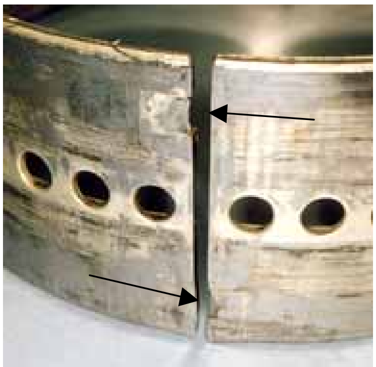
Figure 2. Internal surface of a fragment of the cylinder liner – shows very similar characteristics to the piston skirt.

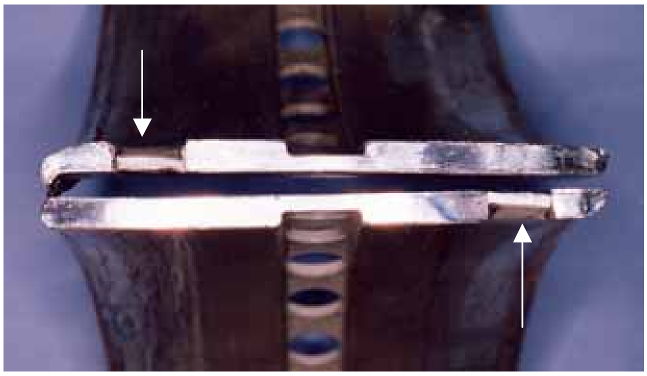
1.6. Connecting rod, bearings and bolts

The connecting rod bearing shells from the number-four cylinder assembly had sustained flaring and splaying damage to the forward edge as a result of the axial movement of the shells and subsequent contact with the crank-pin journal radius. The splaying damage was biased to one side of the assembly (figures 3 & 4), suggesting a degree of axial misalignment between the shells and the bearing housing. Both locating tangs at the shell ends had collapsed (figures 5 & 6). The supply of oil to the pistons was channelled via galleries within the crankshaft and through the crank-pin journals into the connecting rods. The axial movement of the bearing shells within the number-four journal had reduced the effective width of the flow path for the oil moving from the crankshaft, though the bearing space and into the connecting rod. The movement of the shells, however, was insufficient to completely obstruct the oil flow.

Figure 3. Connecting rod bearing shells from the number-four assembly. The outward splaying of the forward edge is clearly visible (arrowed).

Figure 4. Internal (running) surfaces of the bearing shells illustrating the forward edge damage and the wiping of the surface white-metal layer.





Figures 5 & 6. Axial movement of the bearing shells while the engine was in operation flattened the locating tangs as shown.

Other than the forward end splaying, damage to the bearing shells was limited to the wiping of the surface bearing alloy (white-metal) layer and transverse scoring of the steel backing. None of the examinations found any evidence of lubricant deprivation and/or overheating of any of the bearing surfaces.

Both connecting rod bolts had sustained a degree of permanent elongation, as determined by comparison against an unused spare bolt. Calculations conducted by ETRS showed that the degree of permanent elongation sustained by the bolts was sufficient to produce the loosening noted in the Chief Engineer's report. It was noted however that the manufacturing tolerance on the bolt length was 0.5 millimetres and thus the results of the evaluation may not be valid.

Minor fretting and galling damage was reported over the mating surfaces of the connecting rod bearing cap and also noted on the bearing surface of one of the connecting rod nuts. Fretting and galling damage is produced between surfaces in compressive contact that are subject to relative movement. The presence of such damage on the bearing cap and bolt surfaces implies the absence of appropriate bolt tension levels at some time during the life of the assembly.

1.7. Lubrication system

The lubrication system of the VASA 6GR 32 engine, like that of many large reciprocating engines, performed the dual functions of lubrication and cooling. Oil delivered through the connecting rods was distributed beneath the pistons to cool the crown regions, before being fed to the cylinder walls and escaping back to the crankcase. In such arrangements, it follows that the temperature of the piston crown during normal operation is dependent upon the volume of oil circulated through the piston assembly. Published experimental work conducted to assess the effectiveness of oil cooling found that the temperature adjacent to the crown of an instrumented piston in a small test engine was reduced from 220 C to 170 C when an oil flow of 270 litres per hour was circulated through the piston [from Kempe's Engineering Yearbook 1983, ppF6/34].

1.8. Oil-mist generation

Within the crankcase confines of conventionally lubricated reciprocating engines, mechanical and thermal action on the lubricant generates a suspended oil vapour that, under normal conditions, remains relatively constant in concentration during engine operation. During conditions of elevated engine friction and distress however, the concentration of oil mist within the crankcase atmosphere will increase, as a result of oil vapourisation on surface ‘hot-spots’. The greater the degree of distress, the greater the oil mist concentration, and as such, the measurement and trending of oil-mist levels within an operating engine can provide a useful condition monitoring tool [from ‘Oil Mist Detection as an aid to Monitoring an Engine’s Condition’ Brian J. Smith].

In this instance, an alarm from the engine’s oil-mist detector was the first indication of the breakdown that was to follow.

2. ANALYSIS

2.1. Engine failure

The failure of the *ANL Purpose's* main engine was a direct result of the break-up and destruction of the piston assembly from the number-four cylinder of the engine. The severe mechanical damage prevented continuing engine operation and the nature and extent of the damage made repair at sea unfeasible. Analysis of the piston fragments found evidence that pre-existing fatigue cracking within the piston body had contributed to the break-up. Similar cracking was subsequently found within the gudgeon supports of two other pistons from the engine.

The failed piston had an accumulated time since overhaul of 2,195 hours and a total time-in-service of over 87,000 hours. Overhauls were generally required every 12,000 hours, with close inspection and crack detection required at 24,000 hours and each overhaul thereafter. A major overhaul was also due after 64,000 hours of service, with the manufacturer indicating this should have included comprehensive piston inspection and crack-detection. Although no procedures were available for the inspection of the original one-piece pistons, the manufacturer's published inspection procedure for the newer two-piece pistons specifically required the examination of the areas around the gudgeon pin bore and its supports. These were the areas that were found cracked on the pistons from the *ANL Purpose* engine.

Evidence of scoring and associated frictional heating was found on fragments of the piston skirt and the cylinder liner. Distress of this nature suggested problems with piston lubrication and/or temperature control – both of which are regulated by oil flow from the crankshaft and connecting rods. On the basis of the engine design, diminished oil flow volume into the piston would allow the piston crown temperatures to rise, with an accompanying physical expansion. Calculations indicated that for every 100 C increase in temperature, the pistons would expand in diameter by approximately 0.42mm (based on a coefficient of thermal expansion for the piston material of 13.2 x 10^{-6}/C and a nominal piston diameter of 320mm). Overheating conditions would thus present a significant risk of the pistons binding within the cylinder bore/s as a result of insufficient cylinder clearance. Apart from accelerated wear, cylinder binding would also greatly increase the operating stresses within the piston body as the levels of sliding friction increased. Frictional heating and the generation of hot surfaces would produce elevated oil mist concentrations within the crankcase, which should be detected by the monitoring system. Indeed, the chief engineer reported that the engine failure was preceded by the oil mist alarm sounding.

2.2. Connecting rod bearings and bolts

The reasons for the axial movement of the number-four connecting rod bearing shells could not be ascertained from the information gathered during the investigations. It was evident that both shells had moved in unison toward the forward journal radius and that the forces generated to move the shells had been sufficient to flatten the locating tangs. During the bearing shell movement, the displacement of the oil ports in relation to the connecting rod galleries had acted to reduce the available port area for the transfer of oil from the crankshaft into the connecting rod and up into the piston. This throttling effect would have been expected to reduce the quantity of oil available to cool the piston assembly. As noted, the oil galleries were not completely obstructed by the displaced bearings and thus oil flow to the piston would still have been present, albeit at a reduced rate.

The primary retention of bearing shells within the crank-pin journal housing is achieved by the compressive ‘crushing’ action of the housing around the shells. The shell circumferential dimension is sized such that the required clamping force would be generated upon assembly of the housing. Incorrect bearing assembly, such as that warned against in the manufacturer’s service letter (Ref. PG22/32, 22-10-1987), could contribute to a reduction in this retention force and an increased likelihood of bearing movement.

The reported physical elongation of both connecting rod bolts was consistent with their exposure to tensile overloading conditions. Tests conducted by ETRS Pty Ltd showed that the elastic strain induced by the normal tensioning of the bolts was approximately equal to the measured plastic extension of the bolts. That finding was consistent with the discovery of the bolts at low tension levels during the post-failure inspection. It was noted however that as a result of manufacturing tolerances, the original length of the bolts could vary by as much as one millimetre (±0.5mm) and thus the determination of extension by comparison against another item may have been invalid. The light galling damage noted on the nut faces and the bearing cap joint surfaces was indicative of continued engine operation with reduced bolt tension, however the comparatively low-level of this damage suggested that this period was relatively short. Break up and destruction of the piston would have been expected to generate transient high level loads within the connecting rod assembly and it was considered likely that these loads contributed to the bolt damage.

3. CONCLUSIONS

3.1. Findings

The *ANL Purpose* main engine failure occurred due to the partial seizure and consequent fracture and break-up of the piston from the number-four cylinder assembly.

First indication of engine failure was the detection of elevated crankcase oil mist levels due to increased friction within the cylinder.

The presence of pre-existing fatigue cracking within the body of the number-four piston had contributed to the failure.

Two other pistons from the engine were also cracked in a similar manner.

In-service cracking of the pistons was a known design issue and the engine manufacturer had published enhanced inspection requirements for pistons that have accrued more that 24,000 operating hours. A later service letter published service time limits for the main components of the VASA 32 engines. At the time of the failure, the pistons from the *ANL Purpose* had a service time well in excess of the published limits for piston replacement.

The connecting rod big-end bearing shells had migrated forward of their normal positions and had sustained damage as a result of contact with the crankshaft journal radius.

Movement of the bearing shells had partially obstructed the oil flow pathway between crankshaft and connecting rod / piston. At a constant feed pressure, this would reduce the total volume of oil flowing through the number-four assembly.

Control of the piston crown operating temperatures requires that a positive flow of oil be maintained. Any reduction of oil flow volume would be expected to result in an increase in piston temperatures.

An increase in piston temperatures will result in the physical expansion of the piston body, reducing the bore clearances and increasing the risk of binding and seizure. Evidence of binding and partial seizure was found on fragments of the piston skirt and cylinder bore from the failed engine, although it could not be ascertained at what stage of the failure the damage was sustained.

Binding within the cylinder bores will elevate the loads being transmitted through the piston body. Under these conditions, the presence of cracking or other defects may predispose the component to failure in the manner observed within the main engine of *ANL Purpose*.

Independent investigation into the disabling of the Antigua and Barbuda flag general cargo vessel ANL Purpose in the Coral Sea on 6 August 2001

ISSN 1447-087X
ISBN 1 877071 35 8

1800 621 372

www.atsb.gov.au